PENGEMBANGAN SISTEM KLASIFIKASI PUPUK NPK BERBASIS ALGORITMA SUPPORT VECTOR MACHINE (SVM) MENGGUNAKAN SENSOR MAKRONUTRIEN PADA PERKEBUNAN KELAPA SAWIT

INTISARI

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Peredaran pupuk NPK palsu/*off-spec* menjadi tantangan serius karena dapat mengganggu penerapan prinsip pemupukan 5T dan menimbulkan kerugian, sementara verifikasi mutu pupuk umumnya mengandalkan uji laboratorium terstandar yang membutuhkan waktu, biaya, serta fasilitas khusus. Penelitian ini bertujuan untuk (1) mengembangkan sistem klasifikasi pupuk NPK berbasis algoritma *Support Vector Machine* (SVM) menggunakan sensor makronutrien dan (2) mengevaluasi kinerjanya sebagai metode screening cepat untuk verifikasi mutu pupuk di lapangan. Penelitian dilaksanakan pada Juni 2025–Januari 2026. Data diperoleh dari tiga kelas pupuk, yaitu pupuk asli, campuran, dan palsu/*off-spec*, dengan total 120 sampel (40 sampel per kelas). Penentuan label kelas dilakukan berdasarkan hasil uji laboratorium mengacu SNI 2803:2024, sedangkan fitur masukan model berupa nilai N, P, dan K diperoleh dari pembacaan sensor makronutrien yang mengukur elektrokonduktivitas ion larutan dan mengonversinya ke satuan mg/L. Model dikembangkan menggunakan *pipeline* standardisasi data dan SVM kernel *Radial Basis Function* (RBF). Dataset dibagi secara stratified menjadi data latih (80%) dan data validasi (20%), serta dilakukan pengaturan hyperparameter untuk memperoleh model optimal. Hasil menunjukkan model SVM-RBF mencapai akurasi 0,96 (23 dari 24 sampel validasi terklasifikasi benar) dengan nilai *macro average* dan *weighted average precision*, *recall*, serta *f1-score* masing-masing 0,96. Kelas palsu teridentifikasi konsisten tanpa kesalahan klasifikasi, sedangkan kesalahan terbatas pada irisan karakteristik antara kelas asli dan campuran yang mengindikasikan tumpang tindih fitur pada rentang tertentu di ruang N–P–K. Temuan ini menunjukkan sistem yang dikembangkan layak digunakan sebagai bukti keberhasilan prototipe dan validasi awal pada skala laboratorium untuk mendukung verifikasi mutu pupuk secara cepat.

Kata Kunci: *pupuk NPK; pupuk palsu/off-spec; sensor makronutrien; Support Vector Machine; SVM-RBF; klasifikasi.*

DEVELOPMENT OF AN NPK FERTILIZER CLASSIFICATION SYSTEM BASED ON SUPPORT VECTOR MACHINE (SVM) ALGORITHM USING MACRONUTRIENT SENSORS IN PALM OIL PLANTATIONS

ABSTRACT

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The circulation of counterfeit/off-spec NPK fertilizers poses a serious challenge because it can disrupt the implementation of the 5R (right type, dose, timing, method, and placement) fertilization principle and lead to economic losses, while fertilizer quality verification typically relies on standardized laboratory testing that requires time, cost, and specialized facilities. This study aims to (1) develop an NPK fertilizer classification system using a macronutrient sensor and a Support Vector Machine (SVM) algorithm and (2) evaluate its performance as a rapid screening method for field-level quality verification. The study was conducted from June 2025 to January 2026. Data were collected from three fertilizer classes—genuine, mixed, and counterfeit/off-spec—with a total of 120 samples (40 samples per class). Class labels were determined based on laboratory analysis following SNI 2803:2024, while the model input features (N, P, and K) were obtained from a macronutrient sensor that measures ionic electrical conductivity and converts readings into mg/L. The classifier was built using a standardized preprocessing pipeline and an SVM with a Radial Basis Function (RBF) kernel. The dataset was split using a stratified scheme into training (80%) and validation (20%) sets, and hyperparameters were tuned to obtain an optimal model. Results show that the SVM-RBF model achieved 0.96 accuracy (23 out of 24 validation samples correctly classified), with macro-average and weighted-average precision, recall, and f1-score each reaching 0.96. The counterfeit class was consistently identified without misclassification, while errors were limited to overlaps between the genuine and mixed classes, indicating feature overlap within certain regions of the N–P–K space. These findings suggest that the proposed system is feasible as an initial laboratory-scale prototype and validation for rapid fertilizer quality screening.

Keywords: NPK fertilizer; counterfeit/off-spec; macronutrient sensor; Support Vector Machine; SVM-RBF; classification.